

FIBERBOARD CARTONS FOR EXPORTING GRAPEFRUIT

**ARS-S-21
September 1973**

PREFACE

The research reported in this publication is part of an ongoing effort by the Agricultural Research Service to evaluate new packages, shipping containers, and packing methods together with other means of reducing costs and improving the arrival condition of agricultural food products in overseas markets. The performance and costs of several types of shipping containers for transporting fresh citrus to overseas markets were investigated jointly by the Transportation and Packaging Group, U.S. Horticultural Research Laboratory, Orlando, Fla. and the European Research Unit, Rotterdam, the Netherlands.

Growers and shippers of Florida citrus, container manufacturers, sales organizations, and foreign import firms made the study possible by furnishing facilities, sample containers, and special assistance to the researchers. Dr. John J. Smoot and others from the U.S. Horticultural Research Laboratory assisted by picking, grading, sizing, and treating the grapefruit. Especially helpful were Mr. Howard Baron, manager, International Division, Seald-Sweet Growers, Inc.; Mr. Richard M. Reese, managing director, Corrugated Container Institute; Mr. Charles Seraphine, manager, Vero Beach Sub-Station of Seald-Sweet Growers, Inc.; and the staffs of the following citrus packinghouses: Heller Brothers Packing Corp.; Hogan and Sons Citrus Corp.; Indian River Exchange Packers, Inc.; and Indian River Associates, Inc. Mr. E. James Koch, biometrist, Biometrical Services Staff, ARS, U.S. Department of Agriculture, Beltsville, Maryland, developed experimental designs and analyzed the data to determine significance of carton treatment results.

CONTENTS

	<i>Page</i>
Summary	1
Introduction	1
Description and cost of cartons	2
Laboratory tests	3
Procedure	3
Results	3
Export shipping tests	4
Procedure	4
Results	5
Carton damage	5
Product damage	5
Discussion and recommendations	6

Illustrations

Fig.

1. Citrus shipping carton (typical) and experimental 275-pound panel inserts	2
2. Rear view of completed load of grapefruit in van container, at shipping point, showing recommended air-stack pattern and wooden cargo endgate. Note experimental cartons loaded in bottom three layers of last stack	4
3. Rear view of grapefruit load in van container upon arrival at Le Havre, France with wooden cargo endgate removed. Note good arrival condition with no load shifting	4
4. Grapefruit with seriously deformed surface areas (a total flattened or indented surface area more than 2 inches in diameter)	6
5. Wooden endgate constructed of six 1x4 horizontal crosspieces and four 2x4 vertical uprights. Note placement of horizontal slats against cartons where layers meet	7

Tables

1. Description, specifications, and cost of fiberboard shipping cartons for citrus fruit	2
2. Compressive strength and moisture content of fiberboard cartons conditioned 15 days as 60° F and 88 percent relative humidity	3
3. Average deformation in inches to fiberboard cartons in seven shipments from Florida to European markets	5
4. Percentage of Marsh Seedless grapefruit damaged or deformed in seven shipments from Florida to European markets	5

FIBERBOARD CARTONS FOR EXPORTING GRAPEFRUIT

By Philip W. Hale,¹ Russell H. Hinds, Jr.,² and Thomas Moffitt³

SUMMARY

Grapefruit commercially packed in six types of industry-recommended high-strength telescoping cartons were included in seven van-container shipments to Europe to determine their value in protecting fruit from damage in transit. A conventional carton (railroad container No. 6492) was used as the standard for comparison, and the vans were packed in standard patterns to permit air circulation. Although laboratory tests indicated that the six experimental cartons had compression strengths up to twice as great as the standard carton, they neither protected the fruit nor resisted deformation significantly better than the standard carton. Damage appeared to result primarily from excessive bulge in packing rather than from any physical inadequacy of the cartons. Therefore, it appears that the best means currently available to insure maintenance of quality in overseas shipments of grapefruit is strict adherence to good handling practice, particularly avoidance of excessive bulge in packing.

INTRODUCTION

In 1972 the value of U.S. agricultural exports was more than \$8 billion. Fresh fruits and vegetables accounted for about \$288 million or 3.6 percent of this amount.⁴ While total domestic

citrus production increased, exports of fresh citrus fruits have remained at a fairly constant level since 1965. Total dollar value of fresh citrus exports amounted to \$105 million in 1972.

A number of factors have contributed to U.S. failure to increase fresh citrus exports significantly, particularly to Europe. Fresh fruit and vegetables often arrive in unsalable condition; improper precooling, packaging, loading and handling, and the use of inadequate transport equipment and techniques are among the most common causes. To help identify specific problems, the Agricultural Research Service in 1969 established an overseas research facility in Rotterdam, the Netherlands, to study U.S. agricultural products shipped to western Europe. Hinds, in evaluating fresh fruit and vegetable arrivals, noted that extensive losses resulted from improper packaging.⁵

Many containers used for domestic trips averaging 3 days in transit to markets do not provide adequate protection from overhead weight and the high humidity (90 to 95 percent) experienced during extended (3 weeks or longer) overseas shipments. Research has shown that corrugated fiberboard cartons absorbed considerable moisture during the transit period, causing loss of box strength; this loss of strength leads to severe fruit and vegetable damage in transit and during subsequent warehouse handling.

The objective of this study was to determine if cartons of greater compressive strength than the standard carton would improve the arrival con-

¹ Agricultural economist, U.S. Horticultural Research Laboratory, Southern Region, Agricultural Research Service, U.S. Department of Agriculture, Orlando, Fla. 32804.

² Research leader, European Research Unit, Agricultural Research Service, U.S. Department of Agriculture, Rotterdam, the Netherlands.

³ Industrial engineering technician, U.S. Horticultural Research Laboratory, Southern Region, Agricultural Research Service, U.S. Department of Agriculture, Orlando, Fla. 32804.

⁴ U. S. Department of Agriculture. U.S. Foreign Agricultural Trade Statistical Report, Fiscal Year 1972, pp. 2 and 4. 1972.

⁵ Hinds, R. H., Jr. Transporting fresh fruits and vegetables overseas. U.S. Dep. Agric., Agric. Res. Serv. (Rep.) 52-39, 34 pp. 1970.

dition of grapefruit shipped in van containers to overseas markets.

Six types of shipping cartons designed to specifications recommended by manufacturers were evaluated in seven export shipments. Five of the test cartons were made of heavier paperboard combinations than the standard cartons; two were treated for moisture resistance. The sixth treatment consisted of placing fiberboard inserts against the end panels of the standard carton. The conventional carton was used as a standard for comparison with the six experimental cartons.

The cartons of grapefruit in each test shipment were stacked in USDA-recommended air-stack loading patterns. A wooden cargo endgate was installed in six of the shipments between the last stack of cartons and the rear doors of the van containers to take up the slack space and prevent load shift.

DESCRIPTION AND COST OF CARTONS

Each of the fiberboard cartons studied was a two-piece, full telescope 4/5-bushel carton with inside dimensions of 17x10 $\frac{5}{8}$ x9 $\frac{5}{8}$ inches. Figure 1 shows a typical carton and also the reinforcing

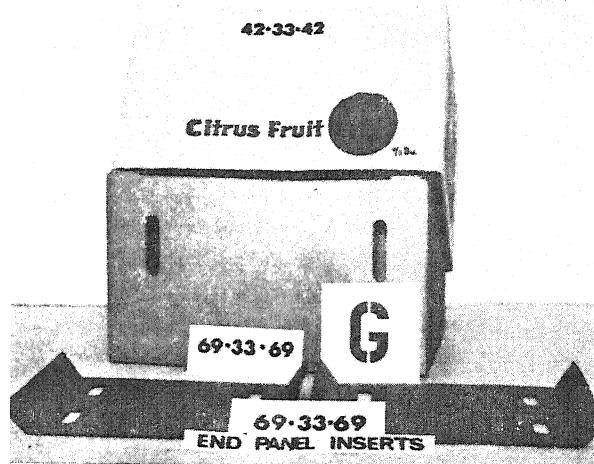


FIGURE 1.—Citrus shipping carton (typical) and experimental 275-pound end panel inserts.

panels used in one of the tests. The cover and body joints of all cartons were secured with moisture resistant adhesives, and all were assembled with a semiautomatic stapling machine. Table 1 contains description, specifications, and cost for all the cartons.

The six experimental cartons cost 1.8 to 8.5 cents more than the control carton. These costs

TABLE 1.—Description, specifications, and cost of fiberboard shipping cartons for citrus fruit

Carton description	Identifi- cation letter	Paperboard weight (lb/1,000 ft ²)		Bursting strength in pounds		Ventilation slots		Cost (cents) per carton ¹	Differ- ence from A (cents)
		Cover	Body	Cover	Body	End	Side		
Standard: Fiberboard, full telescope	A	42-33-42	69-33-69	200	275	2	2	26.8	—
Experimental:									
Fiberboard, full telescope	B	69-33-69	69-33-69	275	275	2	4	31.0	4.2
Fiberboard, full telescope, all flaps meeting (AFM), double medium ²	C	42-33-42	69-(33-26)-69	200	275	2	2	33.2	6.4
Fiberboard, full telescope, wax-dipped body	D	42-33-42	69-33-42	200	250	0	2	32.2	5.4
Fiberboard, full telescope, wax-coated body ³	E	42-33-42	69-33-69	200	275	2	2	35.3	8.5
Fiberboard, full telescope	F	42-33-42	90-33-90	200	350	2	2	28.6	1.8
			69-33-69	200	275	2	2	31.8	5.0

Florida 1971.

^{2,3} has a double medium laminated together in the body of

end inserts constructed of 275-pound paperboard

are based on 1971 manufacturers' average base prices per thousand cartons for carlot quantities delivered to east Florida coast production areas; they do not include printing, color, slotting, or other extra costs, or special discounts and allowances.

LABORATORY TESTS

Two series of tests were conducted to compare the resistance of the cartons to top-to-bottom compression loads. Each compression test series consisted of three replications, in each of which three cartons of each type being tested were compressed in the top-to-bottom direction. Five types were included in Series I and two were included in Series II.

Suppliers of citrus cartons in the central Florida area furnished samples for the laboratory tests from random production runs. Analyses of variance and Duncan's multiple range test were used to evaluate the compression test data.

Procedure

The cartons were preconditioned for 4 weeks in an atmosphere maintained at 73° F and 60 percent relative humidity, then transferred to a conditioning atmosphere at 60° F and 88 percent relative humidity, and held a minimum of 2 weeks before testing. This conditioning atmosphere was selected to simulate closely conditions the cartons were expected to encounter during shipment. The moisture content of the carton covers and bodies was determined with an electrode moisture detector immediately upon removal from the high-humidity conditioning atmosphere.

The test carton was placed on the center of the bottom platen of the laboratory compression tester. The top platen was lowered until it came in contact with the carton. A preload of 100 pounds was applied to the carton. The load was then increased at approximately 15-second intervals until carton failure or maximum load was attained. Carton failure is defined as an abrupt deflection more than 1 inch and maximum load is the weight applied to the carton to cause a 1-inch gradual displacement.

Results

The average compressive strength in the top-to-bottom direction for all six types of experimental cartons was greater than the standard carton (table 2). In Test Series I, all the experimental cartons except carton B are significantly stronger than standard carton A at the 5-percent confidence level. Differences in strength between cartons A and G in Test Series II are statistically significant at the 5-percent level. Cartons D and E (with the wax-coated bodies) had the greatest top-to-bottom compressive strength of any of the cartons. Carton G, modified by placing inserts against each end panel, performed at the third-best level. Cartons C and F performed about the same, while B was the weakest of the six experimental cartons.

The moisture content of the covers ranged from 42 to 53 percent. The moisture absorbed by the bodies was consistently less than the cover for each type of carton, ranging from 32 to 47 percent. The wax-treated bodies of cartons D and E absorbed 5 to 15 percent less moisture than cartons with unwaxed bodies.

TABLE 2.—Compressive strength and moisture content of fiberboard cartons conditioned 15 days at 60° F and 88 percent relative humidity

Carton	Compressive strength (lb)									
	Avg. moisture (%)		Series I replication ¹			Average	Series II replication ¹			Average ²
	Cover	Body	1	2	3		1	2	3	
A (standard)	46	39	475	427	385	429d	392	358	408	386a
B	53	47	525	555	380	487cd	.....	.....	.....	.....
C	42	38	570	575	467	537bc	.....	.....	.....	.....
D	44	33	857	872	815	848a	.....	.....	.....	.....
E	43	32	957	910	783	883a	.....	.....	.....	.....
F	46	37	627	583	530	580b	.....	.....	.....	.....
G	42	39					500	633	722	618b

¹ Three-sample average.

² All values in one column followed by the same letter are not significantly different at 5-percent confidence level, as determined by Duncan's multiple range test.

EXPORT SHIPPING TESTS

To measure the performance of the standard and experimental cartons, seven van container export shipments were made from central and east coast Florida production areas during January, February, and March 1971. One van container was offloaded from the port of Le Havre and moved by highway truck directly to the receiver at the Rungis Market in Paris for local distribution. The other six shipments were unloaded at the receiver's warehouse at the port of Le Havre. Transit time from shipping to destination ranged from 18 to 31 days.

Procedure

All of the cartons were commercially bulge-packed by research personnel with U.S. No. 1, size 40 Marsh Seedless grapefruit. The test cartons were placed in preselected locations in the lower three layers of the two rear stacks of each van container (fig. 2). This location was selected because it is an area in which the greatest damage normally occurs in commercial loads. Each test layer contained one carton of each type randomized within the layer, for a total of 21 experimental and control cartons in each shipment.

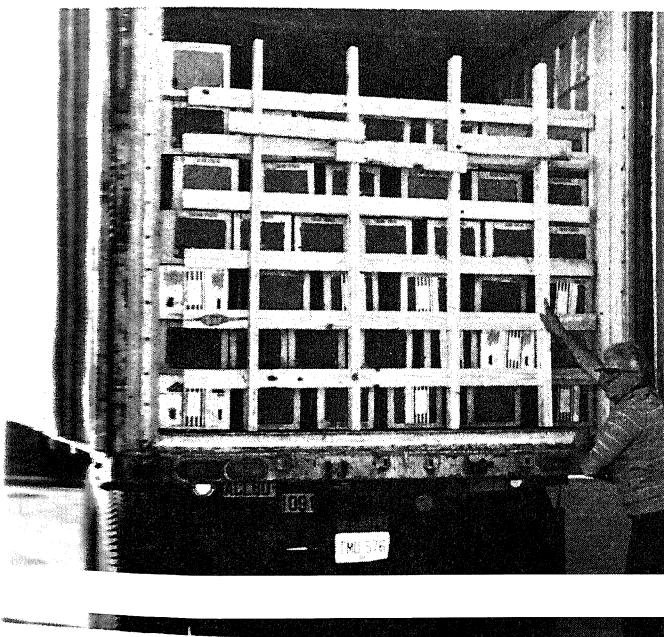


FIGURE 2.—Rear view of completed load of grapefruit in van container, at shipping point, showing recommended air-stack pattern and wooden cargo endgate. Note experimental cartons loaded in bottom three layers of last stack.

Pulp temperatures were recorded at shipping point and upon arrival at terminal markets. Recording instruments placed inside the air discharge duct of each van container continuously recorded temperatures in transit.

At both receiving points, the cartons were manually unloaded and handstacked on 120 by 100 cm (48 by 40 inches) pallets, about 40 cartons per pallet. The pallets were then transported by forklift into temporary warehouse storage and stacked two pallets high. At Le Havre, the cartons were handled and loaded into nonrefrigerated trucks by the same methods and shipped to Paris and other European markets. The test cartons were observed at the time of unloading (fig. 3), and then transported to the USDA's European Research Unit in Rotterdam for further evaluation. Trade reception to the cartons was obtained from the receivers of the seven test shipments.

The amount of damage to the grapefruit packed in the seven cartons was recorded upon arrival at destination markets. The incidence of bruising was recorded in "damage" and "serious" degrees. The incidence of decay and the percentage of slightly and seriously deformed fruit was also recorded. The amount of damage and general appearance of the cartons and their resistance to bottom sag, side bulge, end bulge, and other types of physical damage were determined. A split-plot experimental design was used to test the differences in product and carton damage.

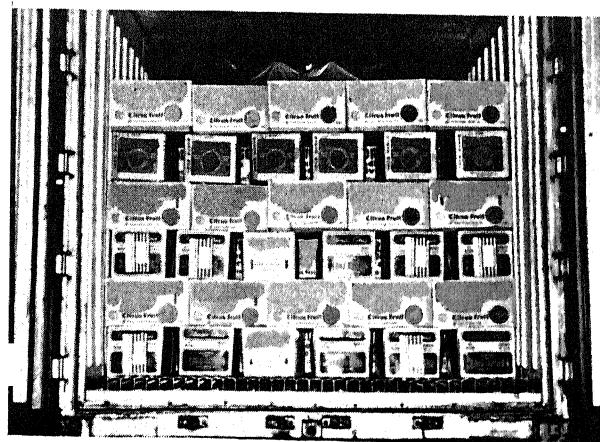


FIGURE 3.—Rear view of grapefruit load in van container upon arrival at Le Havre, France with wooden cargo endgate removed. Note good arrival condition with no load shifting.

Results

Carton damage

Waxed cartons D and E and carton G generally showed the least damage in the commercial fruit shipping tests (table 3). The waxed cartons showed the least compression and were significantly different at the 5-percent confidence level from cartons A and B. However, they were not significantly different from cartons C, D, and G. Carton C with the AFM (all flaps meeting body) style showed the least bottom sag as compared to the other cartons, but the difference was not statistically significant. Cartons D, E, and G, had the least side bulge and were significantly different at the 5-percent level from cartons B and C, but not significantly different from carton A. Carton G, with inserts, and the waxed cartons, D and E, had the least end bulge and were significantly different at the 5-percent level from cartons A, B, and C. Carton G also had significantly less end bulge than carton F. Carton B, with the extra vent slots in the side panels, showed the most damage in all categories. This poor performance is attributed to the fact that the two extra vent slots in the side panels of cover and body accelerate moisture absorption into the corrugated medium of the carton. Waxed cartons D and E, and carton G, with inserts, resisted damage better than the other cartons in the experiment.

TABLE 3.—Average deformation in inches to fiberboard cartons in seven shipments from Florida to European markets¹

Carton	Type of carton damage ²			
	Compression	Bottom sag	Side bulge	End bulge
A (standard)	0.30a	0.63a	0.89bc	1.04a
B	.31a	.63a	.97ab	1.10a
C	.24ab	.52a	1.08a	.95ab
D	.21b	.54a	.80bc	.61cd
E	.21b	.55a	.80bc	.68cd
F	.24ab	.60a	.80bc	.74bc
G	.27ab	.61a	.74c	.49d

¹ Total was 21 of each carton type examined.

² All values within one column followed by the same letter or letters are not significantly different at 5-percent confidence level as determined by Duncan's multiple range test.

Product damage

The amounts of bruising, cuts and skin breaks, and decay in the grapefruit from all cartons were small and not statistically different (table 4). These differences in product damage were too small to be attributed to the types of cartons studied.

However, the amount of deformed fruit found in all cartons, regardless of carton type, was extremely high. Although deformation is not technically considered product damage, the overall appearance of the fruit was seriously affected (fig. 4). Seriously deformed fruit (having flat-

TABLE 4.—Percentage of Marsh Seedless grapefruit damaged or deformed in seven shipments from Florida to European markets

Carton ¹	Bruises ²			Damage		Deformation ⁴	
	Damage	Serious	Total	Skin cuts & b ³	Decay	Slight	Serious
standard)	1.0	0.1	1.1				
	.4	.1	.5				
	.7	.4	1.1				
	.7	.4	1.1				
	.4	.1	.5				
	1.4	.2	1.6				
	.3	.2	.5				

¹ 840 pieces of fruit were examined from each carton.

² Degrees of bruising are defined as follows: Damage affecting 1 segment or less; serious—bruising injury greater than 1 segment or any part of the core.

³ Cuts or skin breaks between $\frac{1}{4}$ and $\frac{1}{2}$ inch long.

⁴ Degrees of fruit deformation are defined as follows: slight—total flattened or indented areas less than 1 inch in diameter; serious—total flattened or indented areas totaling less than 1 inch in diameter as

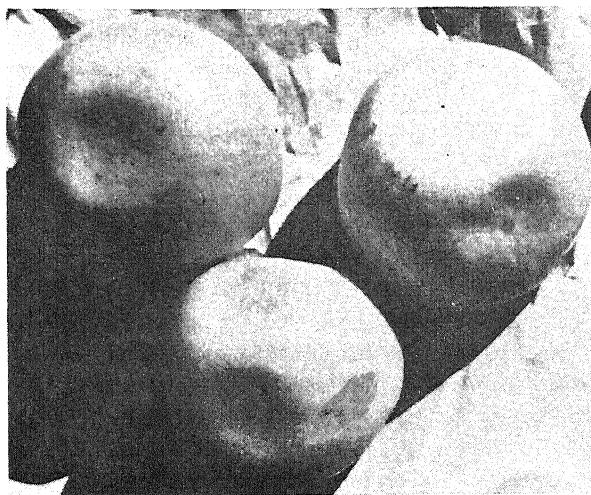


FIGURE 4.—Grapefruit with seriously deformed surface areas (a total flattened or indented surface area more than 2 inches in diameter).

tened or indented areas totaling more than 2 inches in diameter) found in the seven types of cartons ranged from 24.8 to 32.7 percent and there were no significant differences among cartons. Deformed fruit were more prevalent in the lower layers of the loads. Fruit in the upper layers were generally not deformed. This damage was attributed to overhead weight and bulge packing rather than to carton failure.

The commodity temperatures at time of loading ranged from 64.8° to 72.1° F, and averaged 65.9° for the seven shipments. Pulp temperatures at unloading ranged from 45° to 55°, averaging 50.3°. Thermostats for six of the van containers were set on 45°, and one van container thermostat was on 58°.

DISCUSSION AND RECOMMENDATIONS

The experimental cartons, commercially bulge-packed, did not improve the arrival condition or appearance of grapefruit in overseas markets. The amounts of bruising, decay, and other types of damage to the grapefruit were small with no significant difference between types of cartons studied. However, many of the fruit were excessively deformed upon arrival, regardless of the type of carton used. The flat surface areas are detrimental to the overall appearance of the grapefruit, and receivers indicate that this damage adversely affects the fruit's customer acceptance, especially as compared with well-shaped

fruit from Mediterranean areas. The prime cause of the deformed areas appeared to be overpacking, commonly referred to by the trade as "bulge." Measurements of cartons in four packinghouses before shipment showed that fruit in 41.7 percent of the fiberboard cartons were packed over the 1-inch bulge specified as allowable in Florida Citrus Commission Regulation 105-1.03.

Although the two wax-coated cartons performed best with respect to carton damage, and also absorbed the least moisture, most shippers thought the extra cost (5.5 to 8.5 cents more than the standard carton) was prohibitive. Assembling the waxed cartons on hot melt machines was difficult, and when clamp-truck lifts were used to move stacks of the waxed cartons, the cartons in the lower layers slipped out from under the stacks. Some shippers thought the waxed cartons would shift in transit and block the refrigeration air channels. However, container manufacturers indicate that carton slippage can be eliminated by using nonslip additives in the wax.

Following is a list of recommendations to help improve the arrival condition of grapefruit in overseas markets:

1. Pack grapefruit in compliance with Florida Citrus Commission Regulation 105-1.03, which states, "When the telescope cardboard carton is packed with citrus fruit and presented for shipment, the bottom of the telescope cover when in place shall not be more than 1 inch from the bottom of the container when packed with grapefruit (and $\frac{3}{4}$ inch when packed with oranges)."⁶
2. Ship only the highest quality, properly matured grapefruit.
3. Move the fruit promptly from the grove through the packinghouse to the van container or ship's hold, with a minimum of exposure to high temperatures. For export shipments of Florida grapefruit from September to January, a transit temperature of 60° F is recommended, and for the rest of the shipping season, 50°.⁷

⁶ Florida Citrus Commission Regulations, Pursuant to Chapter 601. Florida Statutes, As Amended (Citrus Code), p. 6. 1970. Available on request from: Florida Citrus Commission, P. O. Box 148, Lakeland, Fla. 33802, Attention: Marvin McNair.

⁷ Lutz, J. M., and Hardenburg, R. E. The commercial storage of fruits, vegetables, and florist and nursery stocks. U.S. Dept. Agric. Handb. No. 66, p. 30. 1968.

Relative humidity should be maintained at 85 to 90 percent. Temperature and humidity requirements should also be supplied to receivers to insure proper storage at destinations.

4. Precool the grapefruit to proper transit temperature before loading.

5. Use a loading pattern that will provide adequate air circulation and uniform cooling throughout the load (either an air-stack or a bonded-block pattern with a headstack against the bulkhead).

6. When a space does occur between the last stack and the rear door of the van container, an endgate should be placed against the rear face of the last stack in the load, to fill this void. The gate will prevent load shift, reducing physical damage to the load and preventing blocking of air channels, which, in turn, will insure effective refrigeration of the fruit. Figure 5 illustrates a typical endgate. The average cost of such endgates for the seven export shipments was \$8.30.

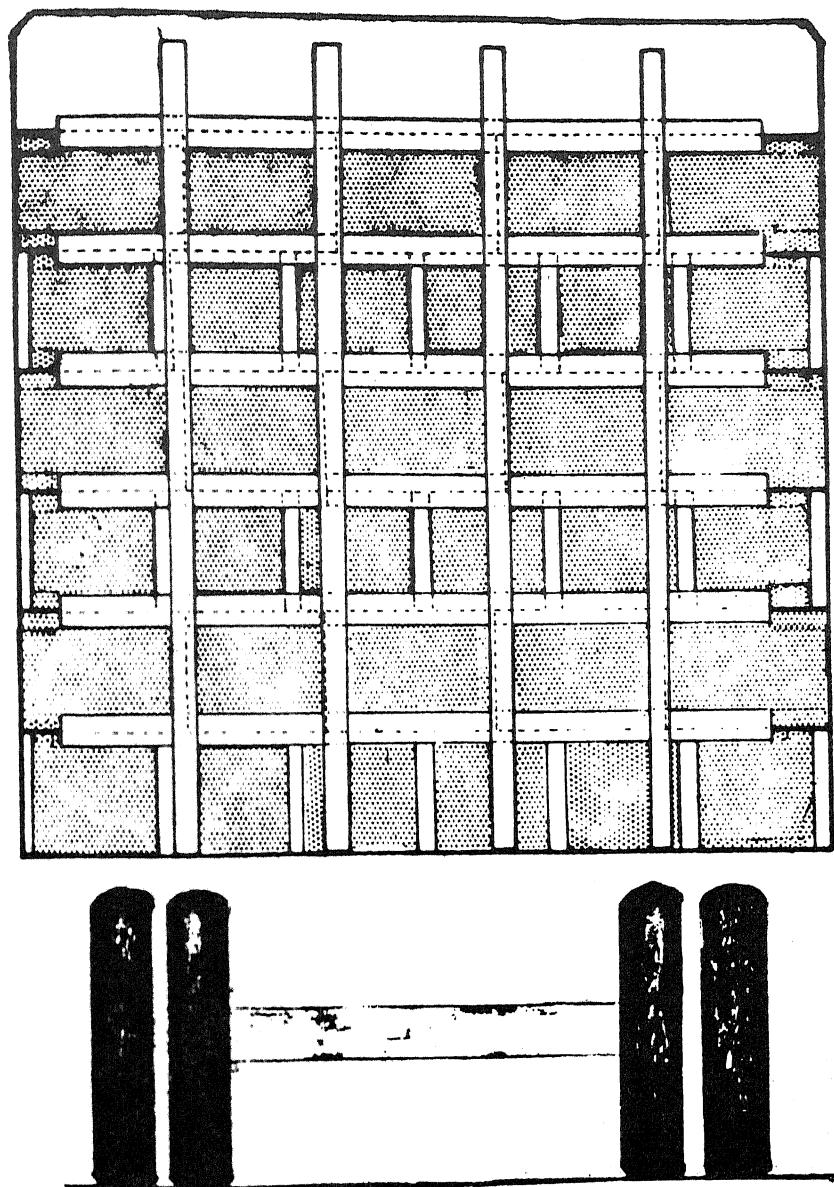


FIGURE 5.—Wooden endgate constructed of six 1x4 horizontal crosspieces and four 2x4 vertical uprights. Note placement of horizontal slats against cartons where layers meet.